Detection electronics results from SM18 - 11T prototype tests

Ernesto De Matteis

Acknowledgements:
D. Blasco Serrano, R. Denz, S. Georgakakis, S. Haas, J. Spasic, J. Steckert & TE-MPE-EP colleagues

Thanks to G. Willering, F. Mangiarotti, M. Duda & SM18 crew for SM18 tests
Thanks to S. Yammine and J. Chailleux from EPC group.

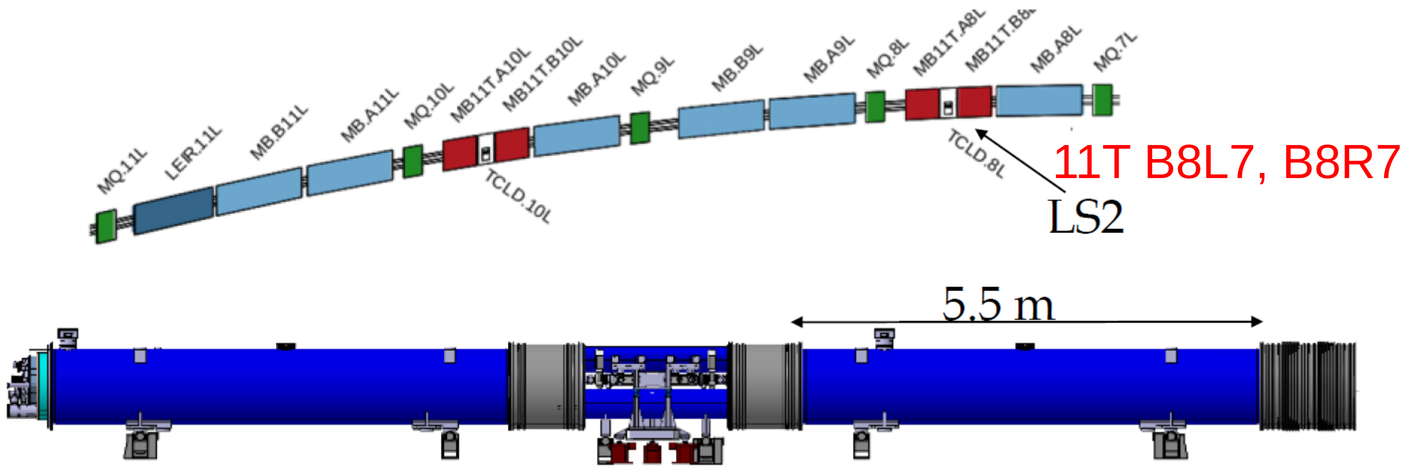
8th HiLumi Collaboration Meeting, Geneva, 15-18 Oct. 2018

Topics

- HL-LHC magnets
- Why a dedicated quench detection system
- Multiple approach system
- Universal Quench Detection System
- SM18 Tests - 11T MBH magnet
- Ongoing activities
- Conclusions

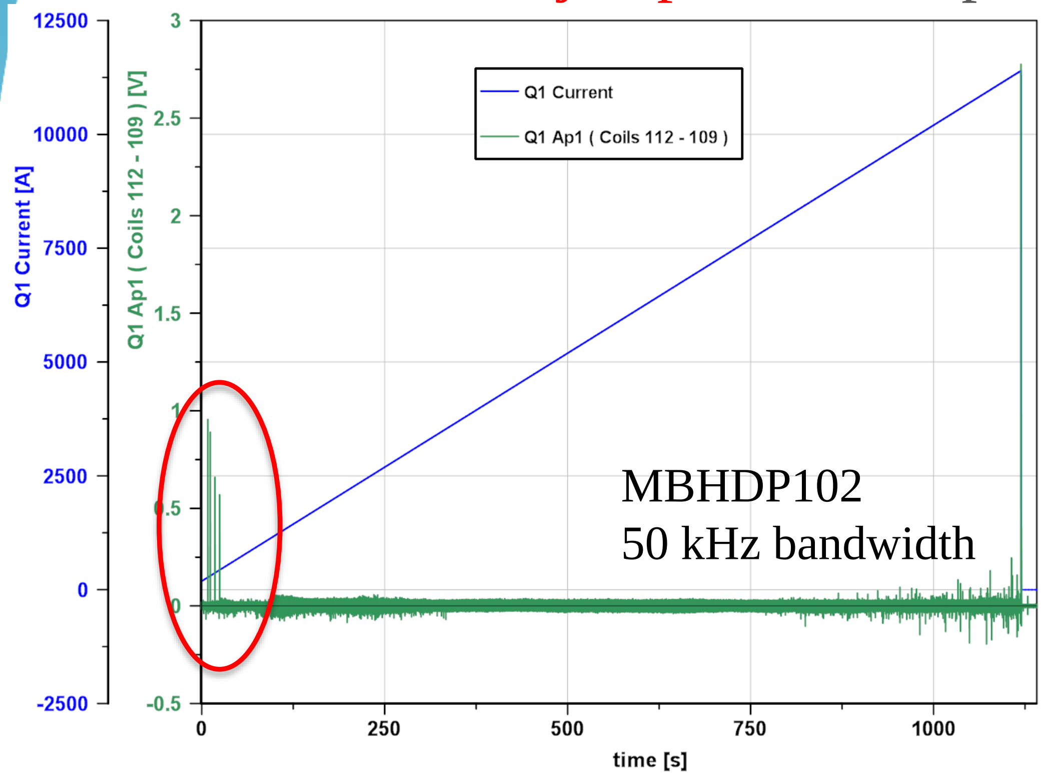
HL-LHC magnets

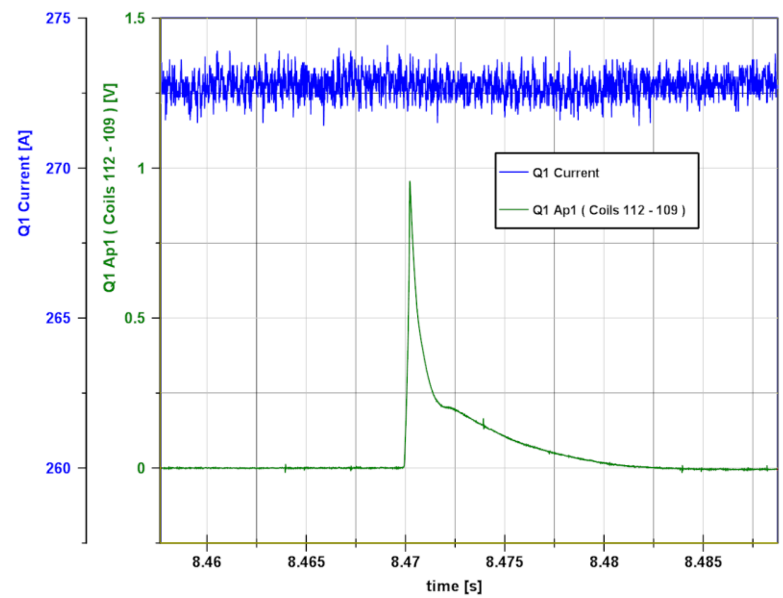
- High Lumonisity upgrade:
  - Novel large aperture <u>Nb_3Sn</u> dipole and quadrupole magnets;
  - new variety of <u>NbTi</u> magnets will be used for the nested orbit correctors (sextupole, octupole, etc..);
  - new superconducting link based on <u>MgB_2</u> for the magnet powering



Why a dedicated quench detection system

- The Nb_3Sn-based magnets show voltage spikes at low field due to the flux jumps on the superconductor.





- The amplitude and duration of these spikes is larger wrt the baseline protection settings (100 mV, 10 ms).

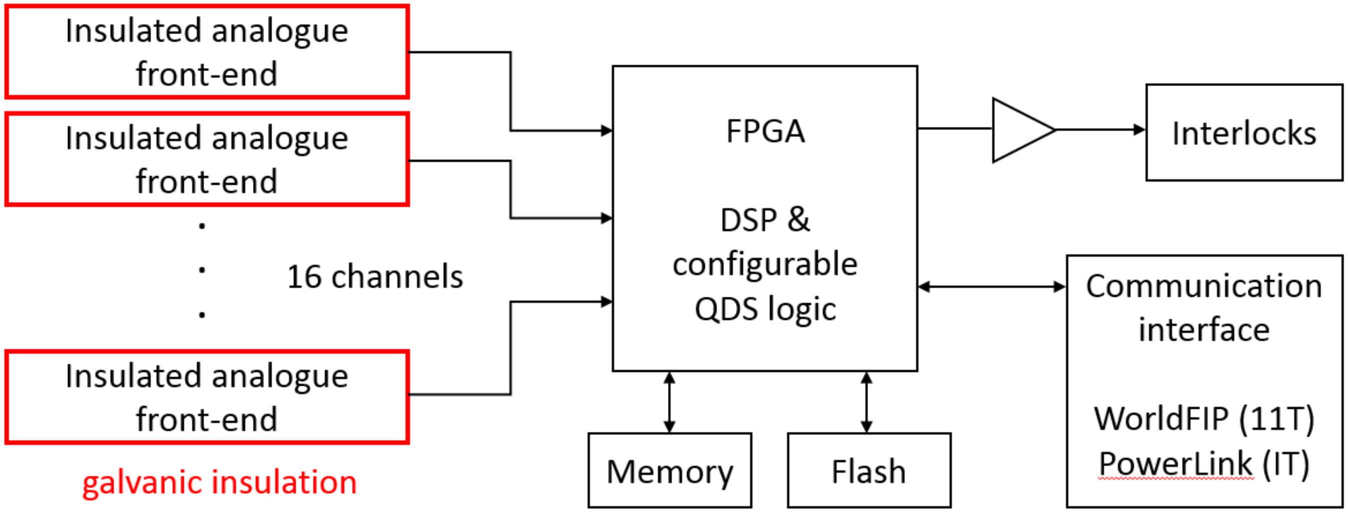
Multiple Approach System

- Quench Detection for HL magnets should cover different needs:
  - Fluxjumps (11T MBH and IT MQXF magnets)
    - Classical evaluation window (100 mV; 10 ms) not applicable;
  - Asymmetric aperture magnets (CCT MCBRDP)
  - Symmetric Aperture magnets
  - Symmetric Quenches

↓

Universal Quench Detection System

Universal Quench Detection System (uQDS)



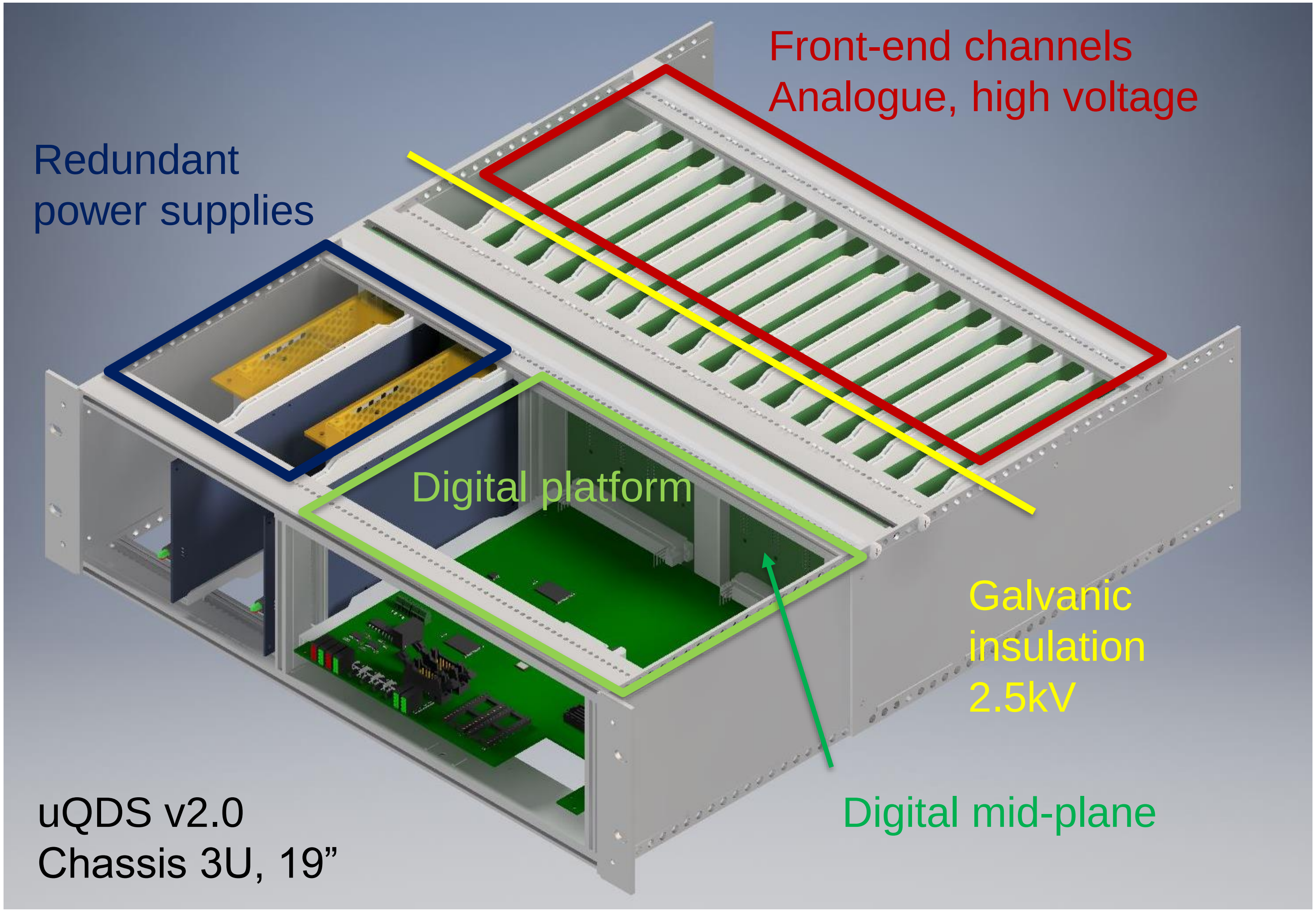
Parameter	Value
Resolution (20-bit ADC)	95nV/LSB .. 43uV/LSB
ADC speed	Up to 1Msp/s
Analogue bandwidth/ gain	125kHz @ G=1 90kHz @ G=9 50kHz @ G=45 7kHz @ G=450
Active input voltage range	+/-50mV .. 22.5V
Max differential input voltage	1kV/1s
Galvanic insulation	2.5kV/20min

- Based on IGLOO2 (M2GL150)
- Supports up to 16 front-ends via mid-plane
- Communication via RS485, USB 2.0, USB 3.0 or WorldFIP

➔ First prototype for 11T QDS

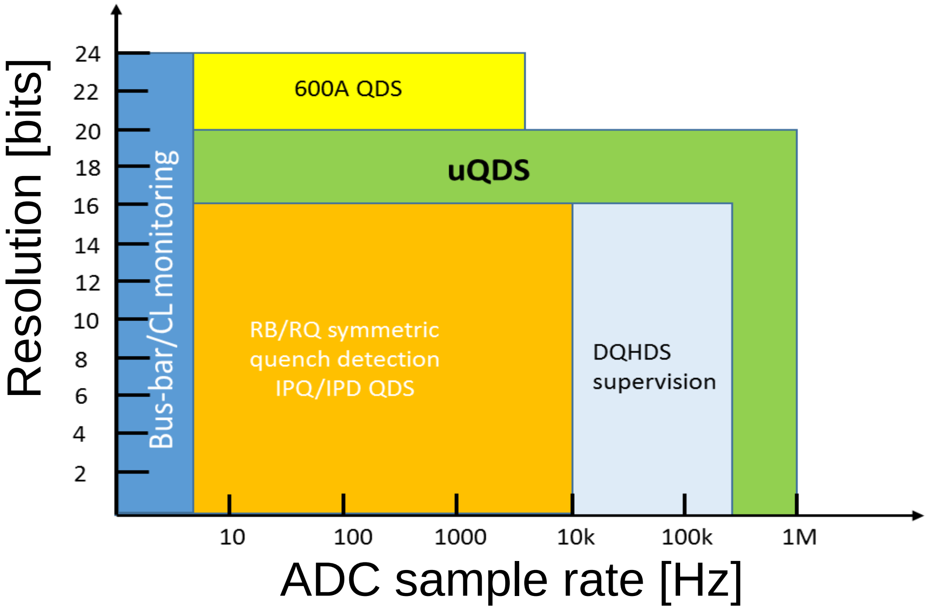
J. Steckert, “Status of detection electronics for 11T protection including trim protection” talk

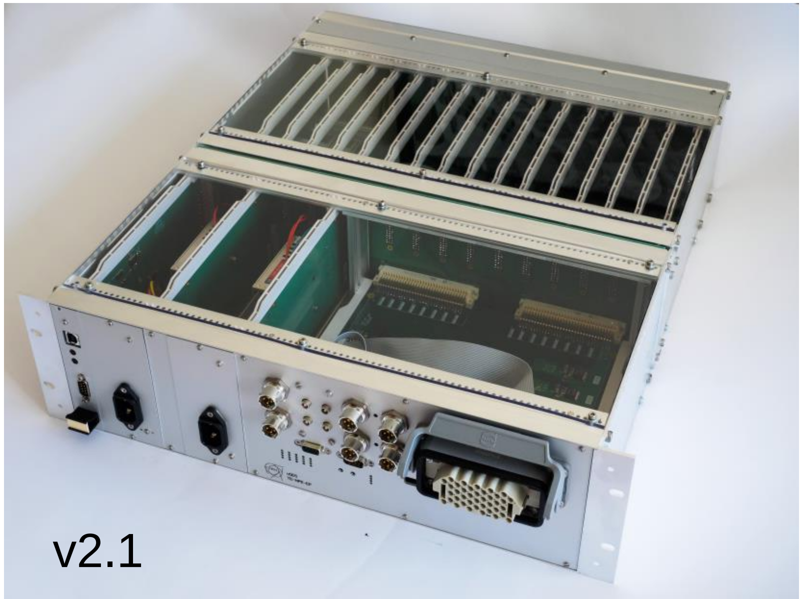
uQDS: system overview



uQDS: Front-end channel

- Challenging design (20bit/1Msps)
- Several prototypes built and evaluated in LHC and SM18
- Serves as universal QDS data acquisition channel
- Covers all existing quench detector requirements



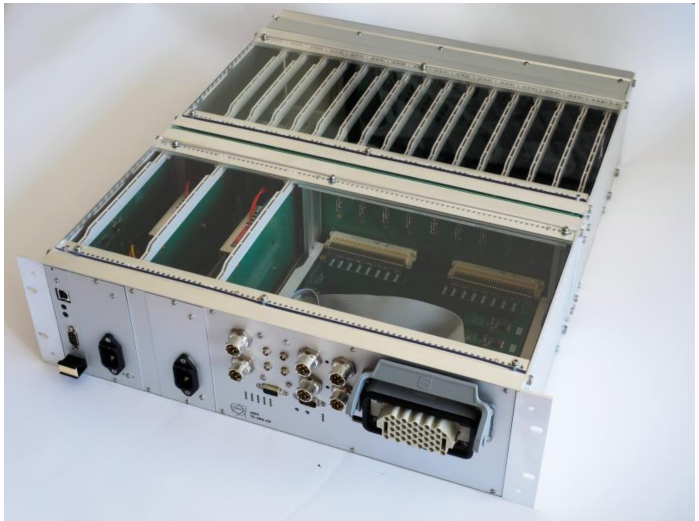


SM18 Tests: Study and validation phase

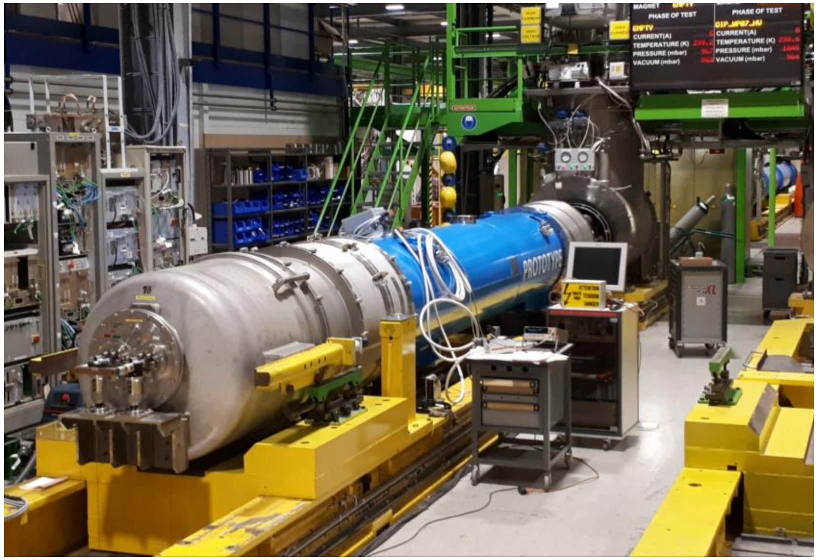
- Following 11T Nb_3Sn magnet development by “testing” uQDS on the new magnets:
  - Study flux-jumps, mechanical oscillations, etc.
  - Estimate what level of filtering is necessary
  - 11T short models: single aperture MBHSP105, 107 and double aperture MBHDP102
  - 11T MBH prototype
- QDS validation:
  - Preparation of the firmware 11T MBH detection system

11T MBH prototype – Measurement setup

uQDS 2.0 used as data acquisition system

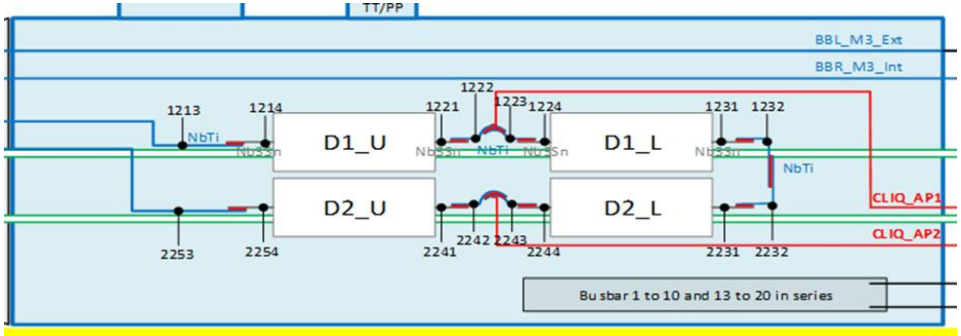


First Nb_3Sn magnet on the SM18 horizontal bench



Acquired signals

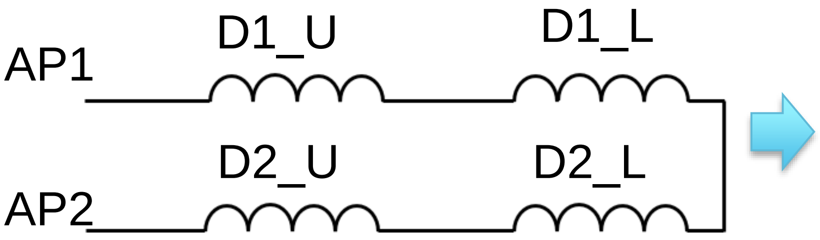
U (D1_U)
U (D1_L)
U (D2_U)
U (D2_L)
I (current)



G. Willering, "MBH prototype test report"- August 2018

11T MBH prototype – Post-processing

- Sampling rate of 500ksps, raw data transmitted via USB2.0
- Signal processing offline:
  - 10us width median filter
  - 50 kHz 10th order Bessel low-pass
  - Decimation by 5



Post-processed signals

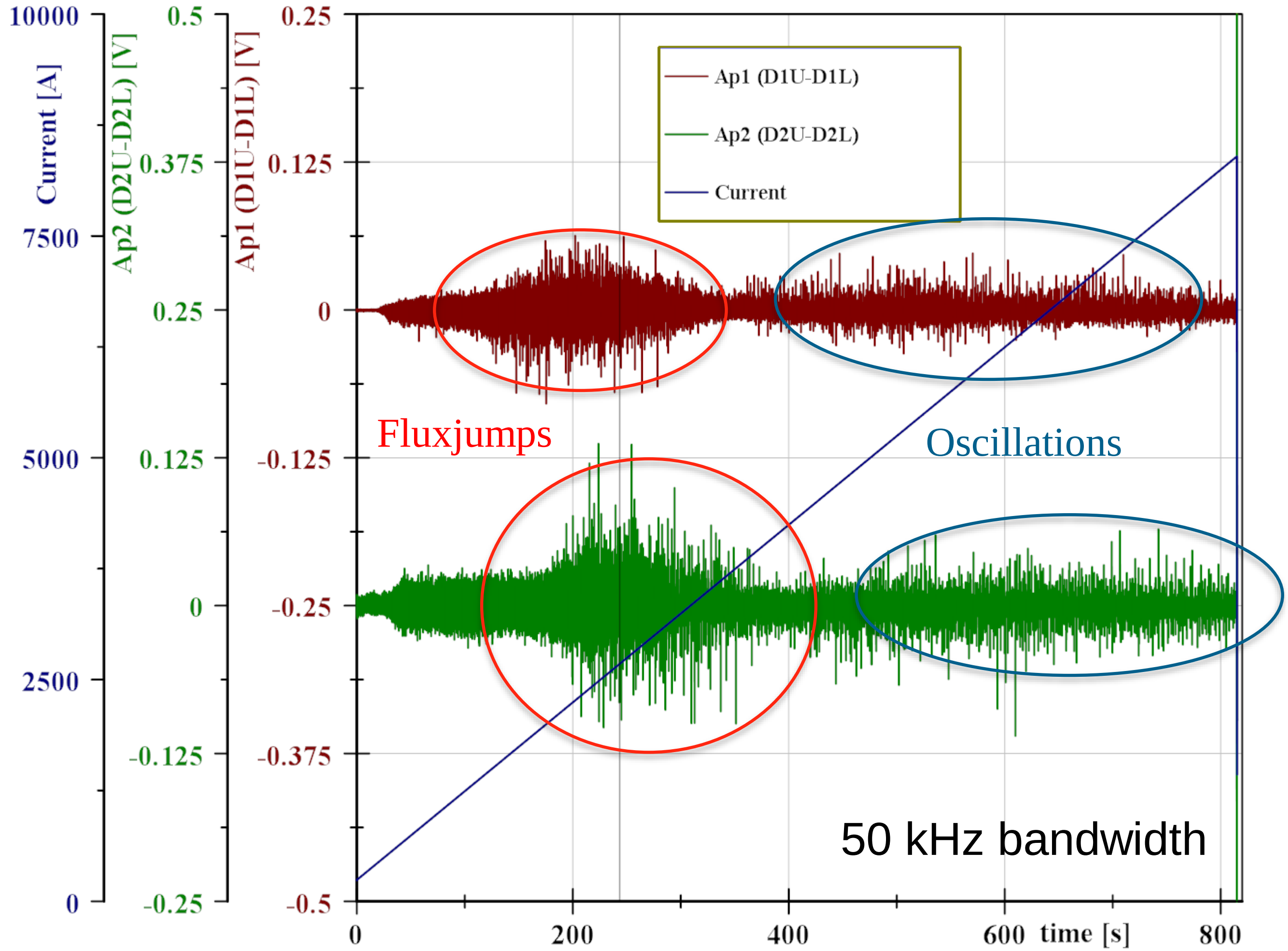
UAp1 = U (D1_U) - U (D1_L)

UAp2 = U (D2_U) - U (D2_L)

Compensated signals used for the quench detection

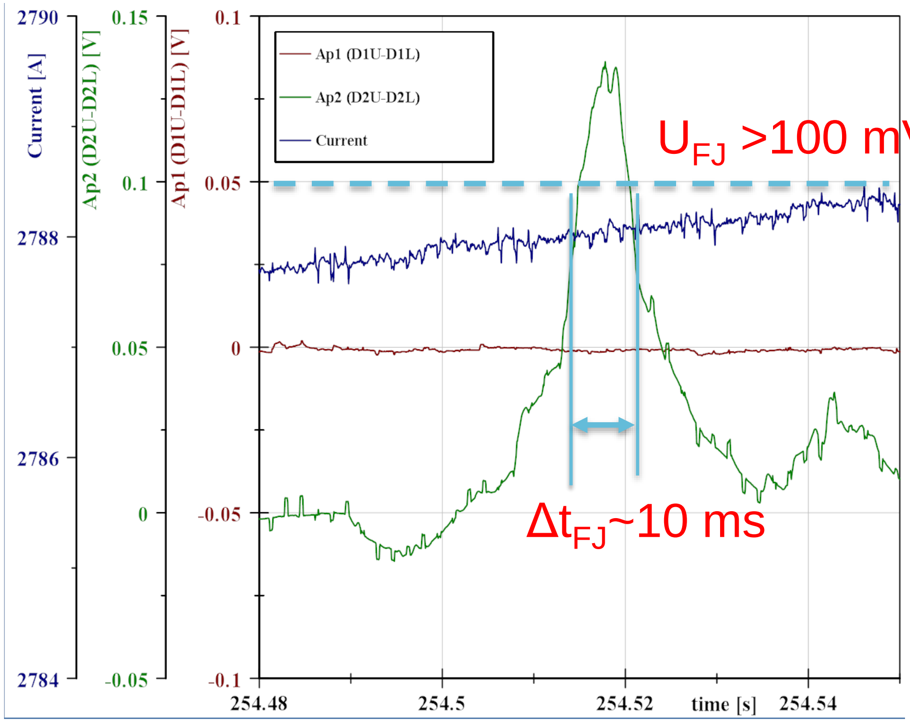
11T MBH prototype – Phase study

- Quench at 8.4 kA



11T MBH prototype – Results

Fluxjumps over the (100 mV ; 10 ms)

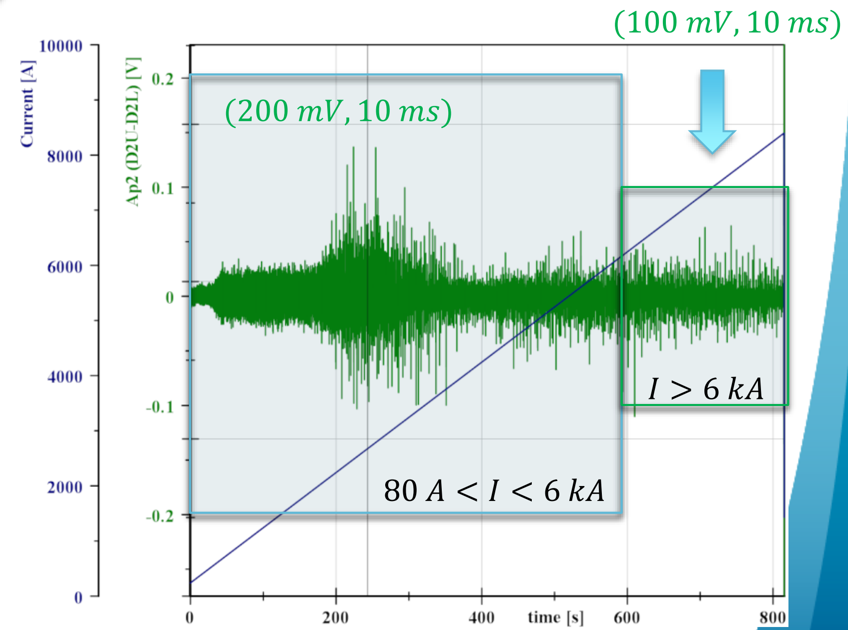


Risk of fake quench
(unwanted effect in the LHC)

Dynamic threshold in amplitude and time to avoid detection trouble due to fluxjumps

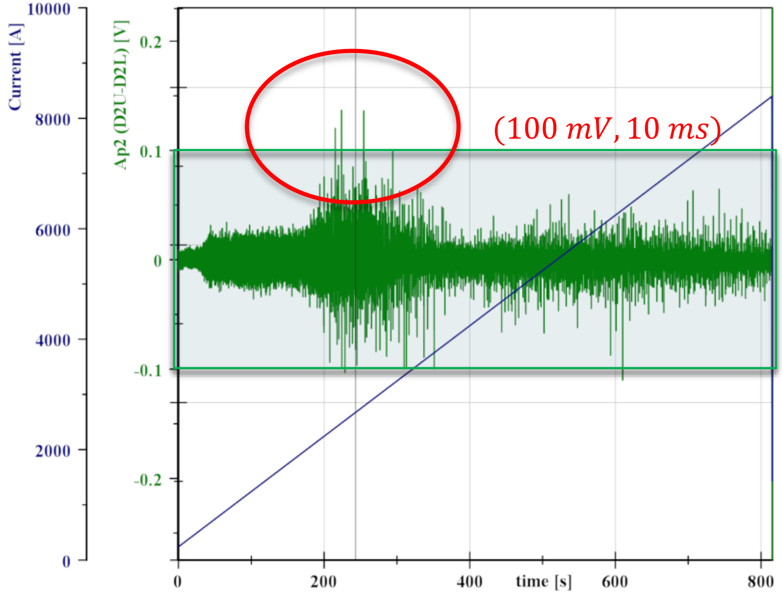
$$(U_{TH}, \Delta t_{TH})(I) = $$

$$= \begin{cases} (2V, 10\ ms) & 0 < I < 80\ A \\ (200\ mV, 10\ ms) & 80\ A < I < 6\ kA \\ (100\ mV, 10\ ms) & I > 6\ kA \end{cases}$$



11T MBH prototype – FJs QD analysis

Standard discrimination window analysis (100 mV, 10 ms)



Peak [V]	Time Loc. [s]
0.106	215.43
0.121	224.00
0.115	254.51

The compensated signal of the Ap2 trip three times

With Ap1 without trips

General method to find a configuration for the dynamic threshold $(U_{TH}, \Delta t_{TH})(I)$

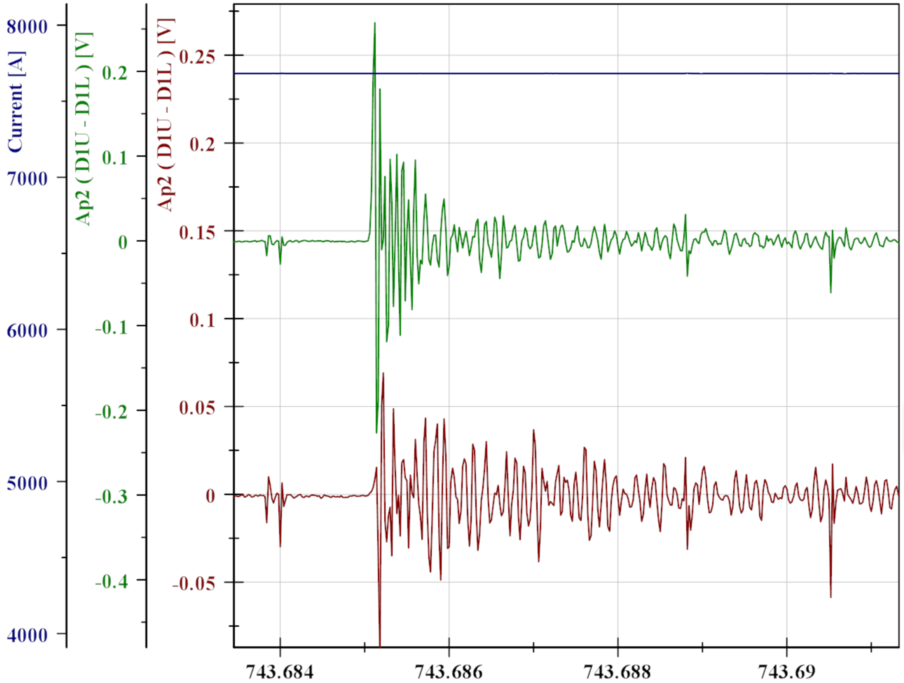
Magnet		Current range	(U_{TH}, Δt_{TH})	# trips
MBHDP102	Ap1	0 – 6 kA	(100 mV, 10 ms)	4
	Ap2	0 – 6 kA		0
MBHSP107		0 – 6 kA	(100 mV, 10 ms)	0

Depending on the magnet training

Each magnet is a different story!!

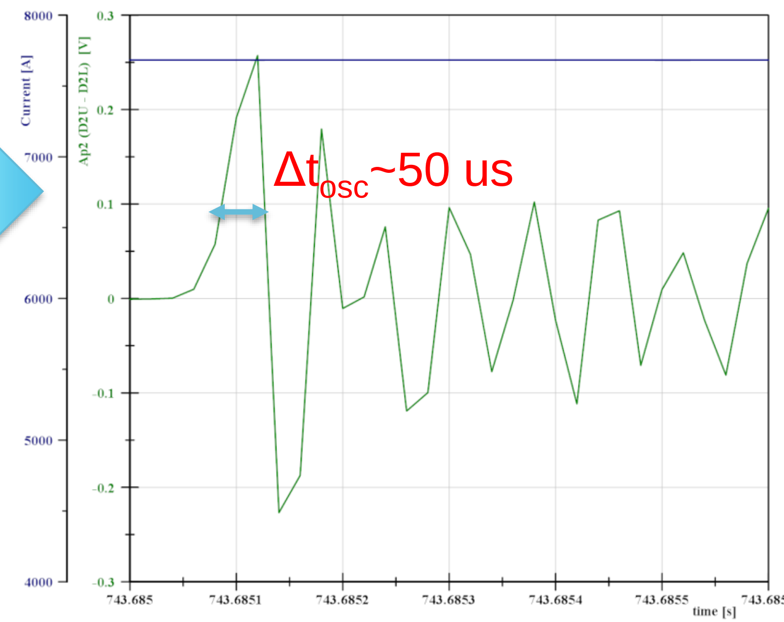
11T MBH prototype – Results

Mechanical oscillations at about 10-15 kHz



Customized filtering:

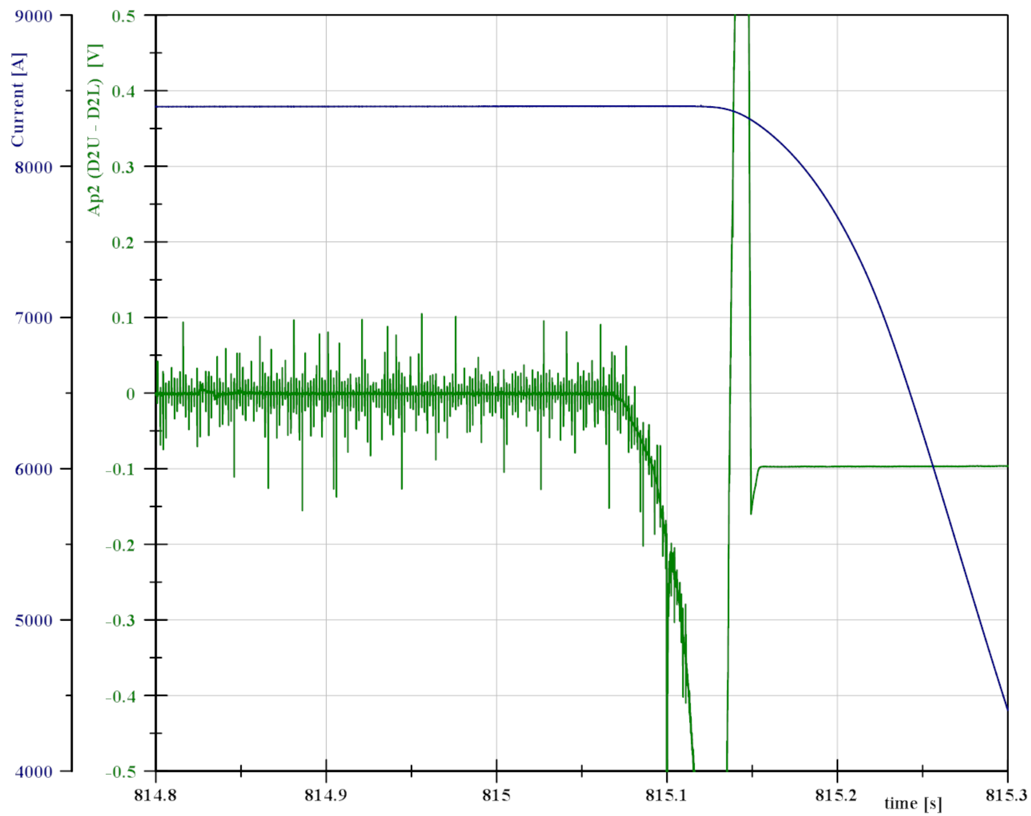
- Median or moving average to remove the power converter noise and attenuate the oscillation effect.



A Median filter of 50 us could be a solution (2-3 samples with a sampling rate of 50 kHz)
Moving average filter of 10 samples
Both easy to implement on the FPGA

11T MBH prototype – Results

Other studies



Emulation of the Logics for the Quench Detection (implemented on the FPGA)

Trigger Verification (timing)

Ongoing Activities

- Validation of the uQDS on the 11T MBH prototype
  - Preparation of the uQDS:
    - Test procedure to qualify the uQDS in the lab (Hardware, and Firmware)
  - Preliminary tests on the CLIC Wiggler magnet
  - Quench Detection Tests on the 11T MBH prototype during the next run
- QDS for CCT MCBRDP prototype (two asymmetric apertures)
  - Validation of the QDS scheme as done on the short model MCBRDS1b

Conclusions

- QDS study phase is continuing (next 11T magnets)
- On-field verification of the uQDS (as Data acquisition)
- A preliminary configuration for the quench detection scheme was fixed:
  - Dynamic threshold (fluxjumps) and relate method
  - Customized filtering and low pass decimation (noise and oscillations)
- uQDS validation is ongoing (next run for the 11T MBH)